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Seasonal and Sex Variation in Physical Activity Levels Among Agro-Pastoralists in Nepal

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ABSTRACT Considerable attention has been devoted to variation in levels of energy expenditure between and within populations; these are commonly evaluated following international guidelines for grading light, moderate, and heavy physical activity levels (PAL). This study presents activity profiles by season and sex for subsistence agro-pastoralists in Nepal, comparing data for a sample of 20 men observed four times across the year with previously published data on women. Total energy expenditure (TEE) was estimated from direct minute-by-minute observation (totaling 1,679 h for men, 3,601 h for women) and measures of the energy cost of single tasks (117 for men, 168 for women). PAL were calculated and graded as multiples of predicted basal metabolic rate (BMR). Despite an explicitly egalitarian organization of labor, men achieved higher PAL than women ($P < .0001$), although according to international gradings, both men and women assume moderately heavy PAL in the winter and very heavy PAL in the monsoon. PAL were 1.88 and $2.22 \times$ BMR for men in respective seasons ($P < .005$; TEE, 11.8 MJ/d and 13.9 MJ/d) and 1.77 and $2.0 \times$ BMR for women (TEE, 9.1 MJ/d and 10.5 MJ/d). High TEE values result from time-consuming work in subsistence tasks, most of which are of moderate energy cost. Results show that the international guideline (FAO/WHO/UNU [1985]) for grading levels of energy expenditure, which adopts discrepant sex-specific values to define thresholds for moderate or heavy PAL, can mask significant gender variation. Male/female ratios of PAL values are suggested instead for population-level comparisons.

A number of detailed field studies, combining measurements of time allocation, anthropometry, energy intake, and energy expenditure, have been conducted in rural Third World populations to measure the overall levels of physical exertion involved in subsistence life styles and their correlates for health (Lawrence and Whitehead, 1988; Norgan, 1992; Durnin et al., 1990). Particularly rich insights into the limits of human adaptability, the biological and social correlates of a range of energetic constraints, and the vulnerability of particular population subgroups have been gained from examining variation in levels of exertion associated with seasonality (Huss-Ashmore, 1988; Ferro-Luzzi and Branca, 1993; Ulijaszek and Strickland, 1993), age (Beall and Goldstein, 1988), sex (Rosetta, 1986), socio-economic differences (Rizvi, 1986), child-bearing status (Prentice et al., 1981; Lawrence et al., 1985), body mass index (Shetty and James, 1994; Durnin, 1994), or household characteristics (Pastore et al., 1993). Levels of energy expenditure are commonly evaluated follow-

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ing the FAO/WHO/UNU (1985) classification of light, moderate, or heavy physical activity levels (PAL, or multiples of basal metabolic rate; James and Schofield, 1990).

A great deal of attention has been focused on communities facing limited food availability, but recent research has also been concerned with communities assuming heavy workloads and high energy turnover. This paper describes the activity levels of adult men in a Nepali agro-pastoralist community characterized by demanding workloads and food self-sufficiency. The working behavior of non-pregnant, non-lactating (NPNL), pregnant (P), and lactating (L) women in this population was described previously (Panter-Brick, 1993a). Briefly, women's workloads showed significant seasonality, increasing from moderately heavy physical activity level (PAL), in early winter to very heavy PAL in the monsoon season. While differences were found between NPNL, P, and L women in the winter, a time of relatively less demanding work, none existed in the spring or monsoon seasons, a period of intensive agricultural activity. Thus women are full-time participants in the labor force, combining both productive and reproductive responsibilities (Panter-Brick, 1989). Men are also involved in subsistence work, participating in agricultural work and assuming primary responsibility for animal husbandry. While ploughing is the sole preserve of men, and brewing beer the preserve of women, other tasks, including subsistence tasks but also cooking and childcare, are shared within the household. The egalitarian basis of labor organization is made absolutely plain in the running of labor groups, where exchanges are calculated on a per day per person basis, without discrimination according to the age, sex, maternal status, physical strength, or fitness of participants.

The present focus on the PAL of men in this community raises a number of questions. First, are workloads equally heavy for men and women, as expected in a community explicitly featuring reciprocal exchange and an egalitarian division of labor? Second, is the seasonality of workloads as pronounced for both sexes? Third, are there relatively few differences among men relative to seniority within or wealth between households, in accordance with women who play down differences related to child-bearing status? An examination of sex, seasonal, and inter-individual variation in PAL is an appropriate focus of analysis for a population having to cope with difficult and variable environmental constraints (steep slopes, poor soils, limited technology, remoteness from market towns, winter frosts, and heavy monsoon rains). In more general terms, this paper will raise an issue regarding how men and women's PAL may best be graded and compared.

MATERIAL AND METHODS

Area and population

One year's fieldwork (1982–83) was undertaken in a Tamang community inhabiting a remote area in the foothills of the Himalaya. The Tamang are the largest ethnic group of Nepal, of Tibeto-Burmese origin, and subsist traditionally from a mixed agro-pastoral economy. The community under study (1,540 inhabitants) is a large nucleated settlement at 1,870 m, exploiting an extensive area (30.7 km^2) of a mountainside rising steeply from 1,350 to 3,800 m. The environment is characterized by dramatic variations in altitude, temperature (mean 10°C in winter, 23°C in the monsoon), and rainfall (mean 4 m/y, 75% of which falls in the monsoon season from mid-June to mid-September). Five cereal crops (paddy rice, maize, millet, wheat, and barley), vegetables, and tubers are planted and harvested in quick succession. A large number of animals (cows, oxen, buffaloes, sheep, and goats) is kept to fertilize fields with manure, provide animal traction, and supply wool, milk, or meat produce. In the early 1980s, the community was self-sufficient in home-produced foods, as households which were short of land exchanged resources with those rich in land but short of labor. Only limited amounts of white rice, salt, spices, kerosene, and cigarettes were purchased from the nearest market town, a full day's walk away.

The Tamang exhibit little socio-economic differentiation within their community. Wealth is briskly re-distributed, rather than accrued, when younger generations claim their inheritance (land is divided equally

among sons, and animals are given to both sons and daughters). Households cultivate small and dispersed terraces, owning on average 0.0124 km^2 in land area. But land-rich families, finding themselves chronically short of hands, will leave some fields fallow or else grant land to others for temporary use or a nominal rent. To ensure productivity, terraces must be manured with animal droppings and to this end, animals are penned in a mobile shelter, a temporary structure of wooden posts and bamboo mats, which is moved from plot to plot every 2–3 days on an annual circuit averaging 19 km. To own a shelter, a household must also have enough humanpower to herd and look after the animals full time. The balance of resources in land, animal, and labor is reflected in a household's management of a cattle shelter, as families either personally own a shelter or join forces to share one. A distinction is made in this article between "owners" and "sharers" of a cattle shelter, as a proxy variable for socio-economic status, potentially affecting working behavior. This is a simple index of wealth, explicitly acknowledged by the population, which summarizes a household's assets in land, animal, and labor.

Sample

Villagers participated in measurements of time allocation, food intake, energy expenditure, and anthropometry. This paper presents time allocation and energy expenditure data for 20 adult men, for whom repeated measures were made in four seasons of the year. They were 20 to 55 years of age, including 12 senior (head of household) and eight junior (married or unmarried sons) males, 16 owners and four sharers of a cattle shelter (proportions characteristic of the general population). This focal group comprises the adult men of 31 Tamang households, originally recruited by Koppert (1988), willing to participate in daily follows and measurements of energy intake and expenditure throughout the year. The sample was small but representative of the village population in terms of household composition and socio-economic characteristics (Panter-Brick, 1989), and constituted 32% of households in one nucleated hamlet and 12% of all households on the mountainside.

Behavioral observation

Individuals were followed continuously throughout the day, wherever they happened to travel on the mountainside, and their activities were recorded minute by minute by four well-trained local assistants. Two individuals (men or women) were observed on any 1 day, working through the sample by arbitrarily selecting different subject pairs for daily study. The period of daily observation increased from 660 minutes in the winter to 780 minutes in the summer (11–13 hours) to reflect changes in daylight.

The sample was observed four times during the year, in November–December (early winter) 1982, January–March (late winter), April–June (spring), and July–September (monsoon) 1983. Individuals were observed for daily variation on two non-consecutive days per season (except in the first months of fieldwork, when only 14 men were included on a single day). In total, minute-by-minute time-allocation data for men were collected over 1,679 hours of observation (141 single days, or 75 seasonally paired observation days) throughout the year.

Energy expenditure

The energy cost of self-paced activities was measured by indirect calorimetry with a Douglas bag and Kofranyi-Michaelis respirometers. A total of 117 measures were made on the men, focusing on tasks demanding in time or effort. Basic tasks were sitting at rest, ploughing with oxen, chopping dead wood with a large "kukhri" knife, walking with a load less than 10 kg, and carrying heavy (10–39 kg) to very heavy (40–75 kg) loads with a head yoke on slopes of different inclines. All participants were recruited at their place of work during normal activity. Energy expenditure was derived from the oxygen content and measured volume of expired gas, following Durnin and Passmore (1967), as detailed in Panter-Brick (1992, 1993a).

Other measures

Anthropometric measures were made at 3-month intervals following standard procedures (Weiner and Lourie, 1981). Birth dates are known accurately (with reference to lu-

nar months and 12-year cycles of animal signs in the Tibetan calendar). A weighed food survey was undertaken by Koppert (1988) for a period beginning with the previous spring and monsoon seasons (in 1982) until early and late winter (1983). Both raw ingredients and individual portions of cooked food, snacks, and leftover were measured, for 3 to 7 days per season, with a beam-balance scale by two local assistants. The measures of energy intake and expenditure were carried out on the same individuals, but not simultaneously during the calendar year.

Procedures for analysis

Activities of Tamang men. These are described on the basis of behavioral observations at four different times of the year. Tasks were grouped into two categories, outdoor/subsistence and indoor/domestic activities. The former includes agriculture, animal husbandry (herding, milking, and feeding animals), work in the forest (collecting firewood and fodder, hunting, or fishing), and travel on the mountainside. The latter comprises domestic work (housework, crop processing, crafts), family care (eating meals, hygiene, childcare) and walking about the village. Work and rest time-scores were recorded separately for each activity, as befits a factorial calculation of total energy expenditure. Thus "subsistence work" refers to the sum of time spent in agriculture, husbandry, forest work, and travel (excluding rest), while "total time outdoors" denotes subsistence work plus rest. Observation during 11–13 hours of daylight captured all outdoor subsistence behavior, but not necessarily all work undertaken indoors. Thus, subsistence activities are the focus of this study, and indoor activities are only briefly examined. Time-scores for each person were averaged over pairs of observation days per season.

Total energy expenditure. TEE was calculated by multiplying minutes of work and rest (summed over all hours of observation) by the energy cost of single tasks (estimated from indirect calorimetry measurements of self-paced activities and from values in the literature; FAO/WHO/UNU 1985; James and Schofield, 1990). Basal metabolic rate (BMR) was predicted from individual age, height, and season-specific weight using FAO/WHO/UNU (1985) equations. Following international recommendations, a standard period of 8 hours was allowed for sleep at $1 \times$ BMR, and unobserved activities in the evening time (held indoors) were estimated at $1.4 \times$ BMR. Twenty-four-hour TEE is expressed in terms of gross MJ/d and PAL (multiple of predicted BMR, TEE/BMR), graded for men as light ($1.55 \times$ BMR), moderate ($1.78 \times$ BMR), or heavy ($2.10 \times$ BMR). Single tasks were also graded in terms of energy expenditure according to the classification of Durnin and Passmore (1967).

Energy balance. This was estimated by comparing mean TEE with mean total energy intake (TEI) across seasons. TEI were calculated by Koppert (1988) from weighed individual daily food intake multiplied by the energy value of foods (from laboratory analyses of local staples, and published values from the *Food Composition Table for Use in East Asia* (1972) and *The Nutritive Value of Indian Foods* (Gopalan et al., 1977).

Gender differences in physical activity. These differences were examined drawing from previously published data for 43 NPNL, P, and L women (3,601 hours of minute-by-minute observation and 168 measures of indirect calorimetry; Panter-Brick, 1993a), whose PAL were graded following the FAO/WHO/UNU (1985) cut-off points for women (light, $1.56 \times$ BMR; moderate, $1.64 \times$ BMR; heavy, $1.82 \times$ BMR). Analyses were run comparing men to 19 NPNL women in the first instance, and then to all 43 women, with similar results. Data are here tabulated for men compared to the NPNL women, leaving aside the P and L women.

Statistical analyses

Seasonal, sex, and inter-individual differences were tested using parametric and non-parametric analyses of variance (ANOVA and Wilcoxon tests, run per season and for all seasons combined), with repeated measures for time allocation (Table 2) and TEE (Table 5). Where age differences were tested by ANOVA, sub-samples under or over 25 years were considered, a cut-off significant

TABLE 1. Characteristics of sample individuals[1]

	Men			Women		
	Mean	±	SD	Mean	±	SD
Age (y)	31.4		11.4	37.2		15.1
Height (m)	1.59		0.04	1.50		0.05
Body weight (kg)	52.3		3.5	46.7		5.4
BMI (kg/m^2)	20.7		1.1	20.7		2.1
BMR (kJ/d)	6,254		239	5,209		235

[1] Men (N = 20) and non-pregnant, non-lactating women (N = 19); BMI, body mass index (weight in kg/height in m^2); BMR, basal metabolic rate (predicted from individual height and weight using age-specific FAO/WHO/UNU 1985 equations).

in terms of seasonal anthropometric changes (Panter-Brick, 1996).

The relative impact of chosen variables (season, sex, age as a continuous variable, senior/junior household status, owner/sharer of a cattle shelter, individual number and household number as appraisal of sample heterogeneity) on time allocation was explored with stepwise multiple regressions. Results are only presented for outdoor subsistence activities (Table 3). The determinants of energy expenditure were also assessed by stepwise multiple regressions, with one model specifying season and individual characteristics (Table 6), and another specifying time-allocation data for subsistence/domestic activities (Table 7). Similar results were obtained with considering either TEE or PAL as the dependent variable. Only results for all seasons combined are tabulated, although salient results for a given season are discussed in the text. Analyses were conducted using the SAS statistical package (SAS Institute Inc, Cary, NC), with $P < .05$ as the accepted level of significance.

RESULTS

The age and physical characteristics of Tamang men, who are relatively short but stocky, and of NPNL women are shown in Table 1.

Summary time-allocation

Men spent a total of 6.8 hr/d outdoors (subsistence work and rest) in early winter, 6.6 hr/d in late winter, 7.9 hr/d in the spring, and 9.1 hr/d in the monsoon seasons (Table 2). Excluding minutes of rest, they devoted 5.3 hr/d, 5.4 hr/d, 6.4 hr/d, and 7.3 hr/d to subsistence activities in respective seasons. Seasonality per se is highly significant for agriculture, forest work, travel, total subsistence work, and total time outdoors, but not for animal husbandry (ANOVA, Table 2).

Men devoted 38% of outdoor work-time to agriculture in early winter, less than 20% of work-time in late winter and spring, and 65% of work-time in the monsoon (when they transplant shoots of finger-millet and paddy rice, weed, and harvest maize). Forest work correspondingly declines in importance in early winter and in the monsoon, when relatively little time is found to hunt or gather wood in high-altitude areas. Men devote about 1 hr/d to animal husbandry throughout the year. Travel up and down the slopes averages between 1.2 and 2.3 hr/d (excluding minutes of rest).

In addition, men are engaged in domestic work (processing crops, making bamboo mats or load-carrying baskets) and personal or family care. They work indoors for 1.8 to 2.3 hr/d and rest an additional 1.7 to 2.6 hr/d (seasonality fails to reach the 5% level of significance) during the period of daylight observation.

Predictors of time allocation

The only significant predictors of men's total time spent outdoors were season and age, explaining 19% of the variance in a stepwise multiple regression (Table 3). Age differences, however, were specific to the late winter season (ANOVA $P < .003$, with younger men staying longer outdoors). In fact, age (as a continuous variable) predicted rest rather than work time-scores in any given activity. Rest scores also showed inter-individual differences in particular seasons. Some men seized the opportunity to rest while cattle grazed on the mountainside. Some, paradoxically, achieved high rest scores when they joined labor groups (convened to devote the entire day to agriculture), working from dawn to dusk but also pausing frequently to pace themselves and eat meals (one man, for example, worked 348 min/d and rested 316 min/d in the fields).

There was little inter-individual differentiation of time-scores except for agriculture in the spring ($P < .003$) and monsoon ($P < .0002$; one man engaged all day in do-

TABLE 2. Time (minute/day) spent in outdoor subsistence and indoor activities observed during daylight hours in four seasons[1]

Activity	Early winter (Nov–Dec) Mean ± SD		Late winter (Jan–Mar) Mean ± SD		Spring (Apr–Jun) Mean ± SD		Monsoon (Jul–Sep) Mean ± SD		ANOVA
Men									(1)†
Outdoors									
Agriculture	122.9	125.6	47.4	68.4	76.2	105.7	281.6	158.2	***
Husbandry	60.9	84.3	67.7	86.4	59.8	78.8	63.1	89.0	NS
Forest work	33.6	38.0	82.7	66.7	114.0	118.7	19.9	36.7	***
Travel	105.0	53.9	121.6	70.7	134.6	98.5	70.1	33.5	*
Rest	85.4	70.6	75.3	50.3	86.3	38.0	108.1	81.1	NS
Total	407.8	145.8	394.8	132.9	470.9	123.0	542.8	174.6	**
Indoors									
Domestic work	87.6	87.7	93.2	90.0	51.7	38.0	75.3	109.9	NS
Family care	32.4	16.2	44.0	14.0	43.2	19.3	34.1	18.1	NS
Walk about	18.1	21.5	9.1	13.2	11.4	16.7	9.0	10.3	NS
Rest	114.0	55.5	138.9	68.0	153.3	95.0	99.3	62.7	NS
Total	252.5	252.2	285.2	116.2	259.6	118.2	217.7	170.6	NS
Women									(2)‡
Agriculture	158.5	105.9	81.0	78.1	156.8	138.9*	305.9	168.4	NS
Forest work	14.6	21.2	18.6	21.5****	23.5	40.8****	0	—*	****
Travel	79.6	47.6	83.4	44.9*	98.0	49.2	58.3	32.1	**
Domestic work	120.0	83.3	160.6	98.1*	132.1	92.2**	115.0	108.7	**
Walk about	12.1	10.6	14.9	14.3*	9.5	7.2*	11.5	9.3	**

[1]N, based on pairs of observation days (daylight hours, 660–780 min/d) per season: for men, N = 14 in Nov–Dec and 20 in Jan–Mar, Apr–Jun, Jul–Sep; for non-pregnant, non-lactating women, N = 14 and 19, respectively. Scores for agriculture, husbandry, forest work (fodder and firewood collection), travel, domestic work (housework, crop processing, crafts), family care (meals, hygiene, childcare), and walk about (in the village) are exclusive of rest.

†(1) Significantly different between seasons (ANOVA, repeated measures): $^*P < .05$, $^{**}P < .01$, $^{***}P < .001$, $^{****}P < .0001$.

‡(2) Only time-scores significantly different by sex are shown (ANOVA): $^*P < .05$, $^{**}P < .01$ to $P < .005$, $^{****}P < .0001$.

TABLE 3. Impact of season and individual characteristics on time-scores in outdoor subsistence activities (stepwise multiple regressions in all seasons)[1]

Dependent variable	Significant predictors	Cumulative R^2	For each predictor R^2	F ratio	*P* level
Men only (N = 75 days)					
Agriculture	Season	0.18	0.18	15.8	.0002
Husbandry	Household status	0.20	0.20	17.9	.0001
Forest work	—	—	—	—	
Travel	—	—	—	—	
Sum of work	Season	0.15	0.15	12.3	.0008
Rest	Age	0.08	0.08	6.3	.0146
Total outdoors	Season	0.13	0.13	10.7	.0016
	Age	0.19	0.06	5.0	.0280
Men and women (N = 146 days)					
Agriculture	Season	0.17	0.17	29.5	.0001
	Individual	0.19	0.02	4.2	.0419
Husbandry	Household status	0.12	0.12	20.0	.0001
	Shelter owner/sharer	0.15	0.03	4.4	.0376
Forest work	Gender	0.15	0.15	24.4	.0001
Travel	Gender	0.05	0.05	7.9	.0055
Sum of work	Season	0.15	0.15	24.7	.0001
	Gender	0.18	0.04	6.4	.0123
	Age	0.21	0.03	4.6	.0341
Rest	Age	0.15	0.15	25.4	.0001
Total outdoors	Season	0.12	0.12	19.0	.0001
	Age	0.20	0.08	15.2	.0001

[1]N, paired observation days throughout the year. Sum of work, subsistence activities (total outdoors − rest). Regressions were run for each activity in turn; the independent variables are season, sex, age, senior/junior household status, owner/sharer of a cattle shelter, sample individual No., and household No. Only significant predictors are tabulated.

mestic work instead of agriculture) and animal husbandry (here household status is a better predictor than age or ownership of a cattle shelter; junior household members worked 107 min/d vs. 32 min/d for seniors, $P < .0001$ all seasons combined). No predictors were significant at the $P < .05$ level for forest work, which is undertaken rather opportunistically, or travel, which is a daily requisite for work on the mountainside.

Gender variation in time allocation

While men spent more time in forest work (65 min vs. 14 min/d for women, $P < .0001$) and travel (108 min vs. 80 min/d for women, $P < .006$), no sex differences were recorded for agriculture, animal husbandry, or sum of subsistence work across all seasons (Tables 2, 3). Excluding rest, men averaged 6.1 hr and women 5.3 hr/d in subsistence tasks ($P < .0123$), due to their higher scores in forest work and travel. Total time outdoors (summing both work and rest), however, shows no sex differences (7.6 hr/d for men and 6.9 hr/d for women).

Both household status and ownership of a cattle shelter influenced participation in animal husbandry for the joint samples (90 min vs. 37 min/d for household juniors vs. seniors, ANOVA $P < .0001$; 66 min vs. 24 min/d for owners vs. sharers, $P < .04$). The former variable was specific to men, the latter to women, and their impact was restricted to the late winter and spring. Differentiation in subsistence responsibilities was confined to these two seasons. Thus for agricultural work, gender differences were only recorded in the spring (Table 2, $P < .05$), allowing greater involvement for men in forest work.

Figure 1 summarizes the relative contribution of men and women in outdoor subsistence tasks. Indoor activities were only recorded during daylight hours: Men spent less time in domestic work (76 min vs. 133 min/d for women, $P < .0005$) and walking about the village (Table 2). Family care and rest indoors during daylight hours showed no gender differences.

Energy expenditure

Self-paced tasks measured by indirect calorimetry (Table 4) were graded following Durnin and Passmore (1967). Only walking and carrying uphill required heavy energy expenditure (>30 kJ/min or 7 × BMR). Ploughing, cutting wood, walking, and carrying loads on level ground or downhill required moderate energy expenditure (18–23 kJ/min or 4–5 × BMR). In terms of percentage of body weight, weight of loads averaged 79% uphill, 86% on level ground, and 102% downhill. No relationship was found between gross energy expenditure and the weight of a load, as men appeared to reduce speed in relation to the difficulty of the task. Only slope incline significantly increased energy expenditure (uphill vs. level or down, $P < .0001$; Panter-Brick, 1992).

Men's TEE values, obtained by multiplying time by the energy cost of single tasks, are very high (Table 5) and increase by 18% from early winter to the monsoon season. In terms of the FAO/WHO/UNU (1985) classification of occupational work, men's PAL are moderately heavy in early winter, heavy in late winter, and very heavy in the spring and monsoon.

Energy balance

Comparison between TEE and TEI values serves to indicate the relative magnitude of seasonal changes in energy balance. However, data were not simultaneously collected: Measurements were taken on different days with some overlap in winter months, and in different years in the spring and monsoon. Intakes for the 20 sample men averaged 9.8 (SD 1.3) MJ/d in the spring, 10.2 (SD 1.2) MJ/d in the monsoon, 9.2 (SD 1.2) MJ/d in early winter of 1982, and 11.0 (SD 1.2) in late winter of 1983 (ANOVA for seasonality, $P < .02$). Thus while TEE values are highest in the spring and monsoon seasons, TEI values peak in late winter. Between early and late winter, TEI values increase by 20% and TEE by 14%. Between early winter and the monsoon, TEI increase by only 11% and TEE by 18%. Actual discrepancy between TEE and TEI mean values is large, of the order of 20% of TEE in early and late winter and 28% in the spring and monsoon (TEI-TEE = −2.6 MJ/d in early winter and −3.7 MJ/d in the monsoon). Further comparison with TEI recorded for a larger sample (Koppert, 1988) confirms this degree of diver-

TABLE 4. The energy cost of basic activities for Tamang men in comparison to women[1]

	Men			Women E/BMR	
	E (kJ/min)		E/BMR		
	N	Mean ± SD	Mean ± SD	N	Mean ± SD
Sitting at rest	20	6.14 ± 0.98	1.38 ± 0.20	57	1.39 ± 0.25
Ploughing	11	22.60 ± 2.24	5.10 ± 0.58	—	
Cutting wood with knife	1	17.65 ± —	3.98 ± —	1	3.98 ± —
Walking < 10 kg load					
Uphill	27	33.11 ± 5.71	7.71 ± 1.26	19	6.49 ± 0.88
Level	8	22.46 ± 5.18	5.18 ± 1.15	7	5.32 ± 0.95
Downhill	5	18.85 ± 3.74	4.22 ± 0.84	1	2.89 ± —
Carrying 10–39 kg load					
Uphill	4	29.94 ± 7.12	6.65 ± 1.52	2	5.60 ± 0.11
Level	2	17.92 ± 3.55	4.27 ± 0.93	7	4.34 ± 0.93
Downhill	1	15.20 ± —	3.58 ± —	12	3.64 ± 0.65
Carrying 40–75 kg load (with head yoke)					
Uphill	12	30.36 ± 5.30	6.94 ± 1.23	—	
Level	5	22.62 ± 3.97	5.08 ± 0.98	1	3.99 ± —
Downhill	21	20.75 ± 3.52	4.81 ± 0.77	8	4.19 ± 0.58

[1] E, gross energy (measured by indirect calorimetry). BMR, predicted basal metabolic rate. For women, see Panter-Brick (1993a). Significant sex differences for walking uphill ($P < .0007$) and carrying 10- to 39-kg loads ($P < .057$) only. Loads carried were 54–129% and 21–114% of body weight for men and women, respectively.

TABLE 5. Total energy expenditure by season for 20 Tamang men and 19 non-pregnant, non-lactating women (Mean, SD)[1]

	Early winter (Nov–Dec)		Late winter (Jan–Mar)		Spring (Apr–Jun)		Monsoon (Jul–Sep)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men								
TEE (MJ/d)	11.8	1.3	13.4	2.0	13.9	2.2	13.9	2.4
PAL	1.88	0.20	2.09	0.35	2.18	0.37	2.22	0.33
Body weight (kg)	52.6	5.0	54.7	4.1	54.2	3.2	52.3	3.5
Women								
TEE (MJ/d)	9.1	0.9	9.9	1.3	10.4	1.1	10.5	1.6
PAL	1.77	0.16	1.89	0.22	2.00	0.19	2.01	0.26
Body weight (kg)	45.9	4.9	47.0	5.2	46.8	5.3	46.7	5.4

[1] For men, N = 14 in Nov–Dec and 20 in Jan–Mar, Apr–Jun, and Jul–Sep; For women, N = 14 in Nov–Dec and 19 in Jan–Mar, Apr–Jun, and Jul–Sep; results are similar with N = 14 in all seasons. TEE, total energy expenditure; PAL, physical activity levels (multiples of predicted basal metabolic rate, TEE/BMR).

gence. In this sample, fluctuations of body weight are significant between late winter and monsoon seasons ($P < .0004$), when men average maximum TEI and TEE respectively, losing 4% of maximum body weight (Table 5). Data for larger samples collected in 1982–83 and in 1990–93 confirm the occurrence of significant seasonal fluctuations in anthropometric status, of greater magnitude in men than in women (Panter-Brick, 1996).

Sex differences in TEE

Where the energy cost of tasks could be systematically compared for men and women, no sex differences were found for E/BMR, except that men were faster walking and carrying 10–39 kg loads uphill (Table 4). In terms of gross energy expenditure and also relative to BMR, men achieve higher values than women ($P < .0001$, Table 5). However, according to the FAO/WHO/UNU (1985) which adopts discrepant cut-off points to classify PAL for men and women (Fig. 2), both sexes assume moderately heavy PAL in early winter and very heavy PAL in other seasons.

Predictors of TEE

For the joint samples of men and women, only season and sex had a significant impact on energy expenditure ($P < .0001$; Table 6). In the case of men, seasonality was the only

TABLE 6. Impact of season and individual characteristics on energy expenditure (stepwise multiple regressions in all seasons)[1]

Dependent variable	Significant predictor	Cumulative R^2	For each predictor R^2	F ratio	*P* level
Men only (N = 75 days)					
TEE	Season	0.10	0.10	8.2	.0054
PAL	Season	0.11	0.11	8.8	.0040
NPNL women only (N = 71 days)					
TEE	Season	0.13	0.13	10.8	.0016
	Shelter owner/sharer	0.27	0.14	13.1	.0006
	Individual	0.37	0.10	10.2	.0022
PAL	Season	0.15	0.15	11.9	.0009
	Shelter owner/sharer	0.22	0.07	6.3	.0146
	Individual	0.30	0.08	7.4	.0083
Men and NPNL women (N = 146 days)					
TEE	Gender	0.46	0.46	123.7	.0001
	Season	0.52	0.06	17.1	.0001
PAL	Season	0.11	0.11	17.3	.0001
	Gender	0.20	0.09	16.6	.0001

[1] N, days of paired observation throughout the year. Regressions were run for TEE and PAL in turn; the independent variables are season and individual characteristics as in Table 3. Only significant predictors are tabulated.

TABLE 7. Impact of time allocation in major activities on energy expenditure (stepwise multiple regressions in all seasons)[1]

Dependent variable	Significant predictors	Cumulative R^2	For each predictor R^2	F ratio	*P* level
Men only (N = 75 days)					
TEE	Travel	0.19	0.19	17.5	.0001
	Agriculture	0.43	0.24	29.6	.0001
	Forest work	0.63	0.20	37.9	.0001
	Husbandry	0.67	0.04	8.0	.0060
PAL	Indoor rest	0.31	0.31	32.3	.0001
	Travel	0.51	0.20	29.7	.0001
	Agriculture	0.57	0.06	9.6	.0028
	Forest work	0.70	0.13	31.4	.0001
	Husbandry	0.73	0.03	8.0	.0060
	Family care	0.75	0.02	5.0	.0294
NPNL women only (N = 71 days)					
TEE	Agriculture	0.24	0.24	22.0	.0001
	Travel	0.46	0.22	27.6	.0001
	Husbandry	0.51	0.05	6.7	.0118
PAL	Agriculture	0.25	0.25	23.2	.0001
	Travel	0.48	0.23	30.4	.0001
	Husbandry	0.56	0.08	12.0	.0009

[1] N, paired observation days throughout the year. The independent variables are time-allocation scores of Table 2. All coefficients are positive except for indoor rest. For subsistence work (sum of outdoor activities), variables account for R^2 = 53% of variation in PAL values for men, R^2 = 52% for women.

significant predictor. In the case of women, ownership of a cattle shelter (9.7 MJ/d vs. 10.8 MJ/d for owners vs. sharers, ANOVA $P < .003$, or 2.01 and 1.89 × BMR, respectively, $P < .04$) and residual inter-individual differences were also noted. Analyses, repeated for a larger sample including pregnant and lactating women (N = 219 observation-days for 20 men and 43 women), confirm the above results. The predictors of energy expenditure are sex ($P < .0001$), season ($P < .0001$), ownership of a cattle shelter ($P < .03$), and residual inter-individual differences unaccounted by other variables ($P < .002$), explaining a total 58% of data variability for TEE and 28% for PAL (results not tabulated).

There was little systematic differentiation of TEE or PAL values (sample heterogeneity) across the year, as villagers adopted flexible work schedules and varied their responsibilities from day to day. For men, some inter-individual differences were present in late winter ($P < .0002$) and the monsoon

($P < .003$), but not in early winter or spring. For women, differences between shelter owner/sharers were recorded only in late winter and spring.

In all, the sexes show a broadly similar time allocation across the year, but with men assuming more responsibilities in forest work and women in agriculture (Fig. 1). For men, travel contributes 20%, agriculture 6%, forest work 13%, and husbandry 3% (in addition to indoor rest contributing 31%) for PAL variation (R^2 values in Table 7). For women, agriculture contributes 25%, travel 23% and husbandry 8% (forest work and indoor rest have no impact) to PAL values. Within sex, the sum of outdoor subsistence work accounts for 53% and 52% of PAL variation for men and women, respectively (cumulative R^2 values, $P < .0001$). Indoor activities made little impact on PAL variability, except for resting scores and family care for men (whose opportunity for rest indoors and participation in family care is only occasional). Even domestic work (including pounding crop at a cost of 4.47 × BMR, a task of moderate energy expenditure) predicted at most only 2% of TEE or PAL variation ($P < .08$) for women.

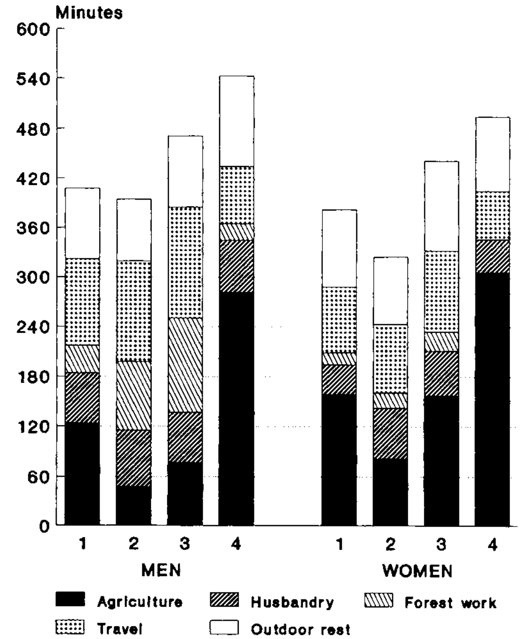

Fig. 1. Time allocation for men and women in outdoor subsistence activities in (1) early winter, (2) late winter, (3) spring, and (4) monsoon seasons (mean per day).

DISCUSSION

Several findings are of interest, with implications for evaluating variation in subsistence workloads and the value of PAL measurements. This discussion evaluates, first of all, the absolute levels of TEE measured in this study, in light of values published for other populations in the literature. Second, it focuses on the sex differences reported for this population, and problems in following international guidelines for evaluating PAL. Third, it highlights some aspects of community and household organization and their impact on the workloads of individual men and women.

First, TEE values for men are high and subject to significant seasonality. Men's PAL are moderately heavy in early winter and very heavy in the monsoon season, TEE increasing by 18%. A relatively small number of subsistence populations achieve such high levels of energy expenditure. In Burma (Tin-May-Than and Ba-Aye, 1985), men averaged light work in the winter and exceptionally heavy work in the monsoon (12.3 MJ/d and 16.1 MJ/d respectively). In Iran (Brun et al., 1979), male farmers were moderately active in winter, very active in summer, and exceptionally active in the autumn (11.0 MJ/d, 14.5 MJ/d and 15.2 MJ/d). In rural Upper Volta (Brun et al., 1979), men averaged light PAL in March and heavy PAL in August at the peak of the rainy season. By contrast, men averaged light PAL in Senegal, very light-to-moderate PAL in the Gambia, and moderately heavy PAL in India (Table 8, where data are available for both TEE and PAL).

High PAL values for Tamang agro-pastoralists can be accepted in light of the quality of data collection (Panter-Brick, 1993a). Sources of errors in the procedure for TEE estimation are more likely to come from a crude breakdown and inaccurate timing of tasks than from simplifying the calculation of the energy cost of daily activities (Durnin, 1978) or relying on the use of FAO/WHO/UNU equations for predicting BMR (Henry

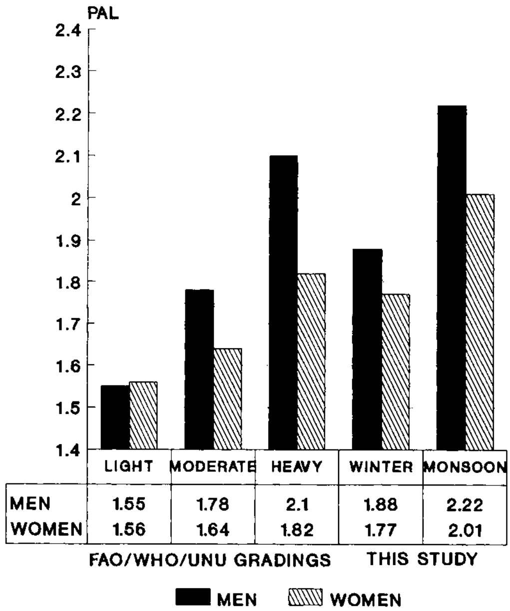

Fig. 2. Physical activity levels (PAL, multiples of basal metabolic rate): FAO/WHO/UNU (1985) gradings for light, moderate, and heavy physical activity level (PAL) (note sex-specific cut-off points) and values for this study (Tamang agro-pastoralists of Nepal) in early winter and monsoon seasons.

and Rees, 1991). In this study, the time spent in work and rest in single tasks was recorded exactly during individual daily follows, generating a huge and very detailed data set (over 5,280 hours of minute-by-minute observation for both men and women). Certainly, an important source of error would arise if habitual activity were modified during actual observation. There was very little interference, however, because local assistants were unobtrusive, maintaining a reasonable distance during the follows of their own kith and kin. The measurements of indirect calorimetry were also well performed by participants recruited at their place of work, which ensured that they kept to the habitual pace dictated by co-workers. There were, however, discrepancies between TEE and TEI values, which suggests overestimation of TEE, underestimation of TEI, or true energy imbalance. Rather large discrepancies are often reported in the literature (Huss-Ashmore, 1996). A useful review of the literature by Ulijaszek (1992) shows that energy imbalances rarely exceed 1 MJ/d where TEE and TEI measurements are taken simultaneously. This is not the case in the present study (measurements were made on the same individuals, but on different days during the winter, and a year apart during the spring and monsoon), and a large discrepancy is therefore not surprising. The imbalance recorded was greater in the monsoon than in winter, and larger for men than for women. Consistent with these observations, seasonal weight losses were significant and more pronounced for men than for women (Panter-Brick, 1996).

Second, gender differences are marked for both TEE and PAL ($P < .0001$). In terms of the FAO/WHO/UNU (1985) classification of activities, however, both sexes assume moderately heavy workloads in the winter and very heavy workloads in the monsoon. International conventions specify single values for activity levels in light work (office clerk), moderate work (subsistence farmer), or heavy work (not specified) for each sex (Fig. 2). These thresholds are discrepant by sex, for reasons which remain unclear in the FAO/WHO/UNU (1985) report, but are perhaps historical, as values adopted to specify gradings of PAL were based upon the data for men and women then available; such data were extensive for Western but not Third World populations, and physical exertion was commonly less for women than for men in Western populations. The original Durnin and Passmore (1967) data and Annex 5 of the WHO/FAO/UNU report (1985; pp. 186–191) present clear sex differences in the energy cost of single activities, but such are not the findings of this study: Except for uphill travel, Nepali men and women in this subsistence population showed no significant differences in the energy cost of given tasks, where measured by indirect calorimetry (Table 4). In 1985, the FAO/WHO/UNU report made a landmark decision in deciding to base energy requirements on PAL rather than energy intakes and recognized sex differences in physiological requirements, but a real justification for upholding sex-specific thresholds to grade occupational work is now open to question.

The international conventions for grading PAL are therefore unhelpful to express the

TABLE 8. Total energy expenditure (TEE in MJ/d) and physical activity levels (PAL as multiples of BMR) for males and females in various subsistence populations

	Males		Females		Male/female ratio
Population (source)	TEE	PAL	TEE	PAL	PAL
Nepal agro-pastoralists					
Dry season	11.8	1.88	9.1	1.77	1.06
Wet season	13.9	2.22	10.5	2.01	1.10
India farmers					
Tamil Nadu[1]	12.0	1.96	8.3	1.69	1.16
Gambia farmers					
Dry season[2,3]	7.6	1.17	9.6	1.68	0.70
Wet season[2,3]	12.5	1.87	11.3	1.97	0.95
Wet season[4]			10.4	1.95	0.96
Upper Volta farmers					
Dry season[3,5,6]	10.1	1.55	9.7	1.88	0.82
Wet season[3,5,6]	14.4	2.15	12.1	2.33	0.92
Senegal farmers					
Dry season[7]	11.1	1.6	11.5	2.0	0.80
Wet season[7]	10.1	1.5	10.0	1.8	0.99
Papua New Guinea farmers					
Coast[8,9]	9.8	1.5	7.7	1.5	1.00
Highland[8,9]	10.8	1.6	9.4	1.8	0.88
Peru farmers					
Machiguenga[9,10]	13.4	2.2	8.0	1.7	1.29
Highland Nunoa[9]	8.4	1.3	6.7	1.3	1.00
Siberia herder/fishermen					
Evenki[9]	11.9	1.8	8.8	1.6	1.13
Keto[9]	11.4	1.7	7.8	1.5	1.13
Paraguay foragers					
Ache[9]	13.9	2.2	11.0	1.9	1.16
Kenya pastoralists					
Turkana[9]	9.0	1.3	7.3	1.3	1.00

[1] Gillepsie and McNeill (1992).
[2] Lawrence and Whitehead (1988).
[3] Reviewed in Ulijaszek and Strickland (1993).
[4] Singh et al. (1989).
[5] Brun et al. (1981).
[6] Bleiberg et al. (1980).
[7] Simondon et al. (1993).
[8] Norgan et al. (1974).
[9] Reviewed in Katzmarzyk et al. (1994).
[10] Montgomery and Johnson (1977).

findings of significant sex differences for agropastoralists in Nepal. Thus the cut-off points chosen to specify heavy activity are 2.1 × BMR for men but only 1.82 × BMR for women; Tamang PAL for the monsoon are for men 106% and for women 110% above these respective thresholds, yet actual PAL values are significantly higher for men than for women. Other than measuring work performance as a percentage of maximum aerobic capacity (VO_2 max; Astrand and Rodahl, 1986; Barac-Nielo, 1987), an alternative way of expressing sex differentiation in activity levels is the simple ratio between men and women's average PAL values (Fig. 3). For the Tamang, this ratio is greater than unity and superior to that reported for pastoralists in Kenya or farmers in the Gambia, Upper Volta, Senegal, Papua New Guinea, and highland Peru (Table 8). It is less than that reported for the farmers of India, the Machiguenga of lowland Peru (for whom sampling may not have been representative), the Ache of Paraguay, and Siberian populations. By comparison, the male/female ratios of FAO/WHO/UNU threshold values are 0.99, 1.09, and 1.15 for light, moderate, and heavy PAL, respectively, but these may be arbitrary discrepancies due to the adoption of different sex-specific gradings.

The findings of significant sex differences in PAL was somewhat unexpected. The Tamang are said to be "an extraordinarily egalitarian group" (Fricke, 1994) with a flexible and egalitarian division of labor between men and women (Acharya and Bennet, 1981), in stark contrast to other agro-pastoralists who favor strictly demarcated

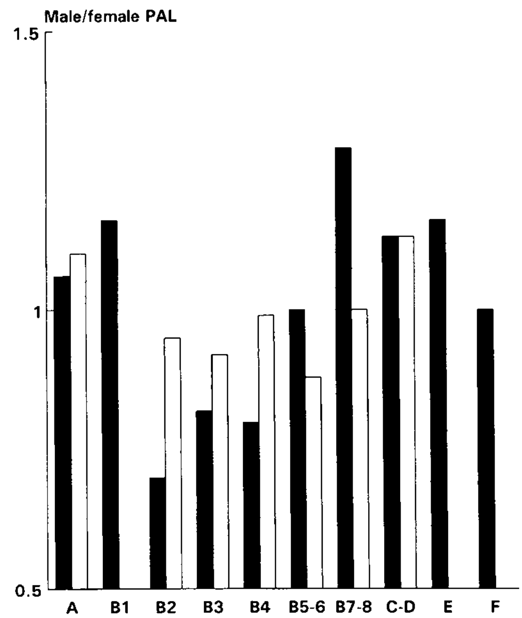

Fig. 3. Male/female ratio of physical activity levels for agro-pastoralists in Nepal (A, winter and monsoon); farmers in India (B1), the Gambia (B2, dry and wet season), Upper Volta (B3, dry and wet season), Senegal (B4, dry and wet season), Papua New Guinea (B5, coast and B6, highland), and Peru (B7, Machiguenga and B8, Nunoa); herders (C, Evenki) and fishermen (D, Keto) in Siberia; foragers in Paraguay (E, Ache); pastoralists (F, Turkana) in Kenya. For references, see Table 8.

spheres of activity (Parkes, 1983). In this community, 1 day's work by an adult man, say ploughing the fields, is deemed the equivalent of 1 day's work cutting fodder by an adolescent girl, or 1 day's load-carrying by a pregnant or nursing mother. Pursuing these equivalences further, any of the above activities will be accepted in return for the daily hiring of one ox, since the work of a human (man or woman) is deemed to match the work of an ox (Panter-Brick, 1989). To some degree, this explicitly egalitarian ethos is substantiated in quantitative terms by this study. Sex differences in outdoor subsistence activities are significant only for forest work and travel, not for agriculture, husbandry, rest, or the total time spent outdoors. Sex differences are noted for domestic work and walking about indoors (but they make no impact on PAL variation) during daylight hours, but at dusk men as well as women participate in domestic tasks (cooking, pounding grain with a foot-operated pestle, or overseeing flour-grinding in a water-mill). Both men and women show a similar seasonality of TEE values (a rise of 15–18% from the winter to the monsoon season). Yet men average consistently higher TEE and PAL values.

It is often said of subsistence farming communities that "men are generally employed in activities with high power requirements (tilling soil), whereas the women are employed in time-demanding tasks (weeding, collecting wood, cooking)" (Giampietro and Pimentel, 1992). Differences in behavior, whereby man commit to subsistence tasks during peak times and women "work hard all year long," often lead to sex differences in TEE and anthropometric changes (Rosetta, 1986). In this community, however, men average higher TEE not because of demarcated responsibilities, but because they shoulder both power-demanding (ploughing, carrying heavy loads) and time-demanding activities (collecting fodder and wood); relative to women, their times in forest work and travel also indicate that they assume greater mobility on the mountainside.

The nature of heavy workloads can only be appreciated with detailed data on the time allocation and energy cost of tasks. It is important to note that TEE are high, not because men repeatedly perform tasks heavy in energy expenditure, but because they spend long hours in outdoor subsistence activities, most of which demand a moderate expenditure of energy. With the exception of travel uphill, self-paced activities measured by indirect calorimetry require moderate energy expenditure (Panter-Brick, 1992). In itself, this is a good indication that individuals pace themselves to sustain long hours at work, which demands endurance rather than intensive effort. Moreover, even urgent agricultural labor during the monsoon season features many pauses for resting and eating meals in the fields. As previously emphasized for women (Panter-brick, 1993a), it may be back-breaking work to subsist in the marginally productive and steep foothills of the Himalaya, but this mostly results from having to work long hours on the mountainside rather than shouldering tasks which are

truly heavy-going in terms of energy expenditure.

Time devoted to agriculture and travel, in particular, influences variation in TEE and PAL. Seasonality in workloads is associated with urgent agricultural tasks during the monsoon rains (work in the fields doubles from early winter to the monsoon, from 2.1 hr/d to 4.7 hr/d for men, and from 2.7 hr/d to 5.1 hr/d for women, excluding rest). Daily travel (1.2 to 2.3 hr/d for men, 1 to 1.6 hr/d for women, excluding rest) takes place on steep slopes of 12% to 35% incline, and contributes to observed sex differences in PAL. The importance of travel over uneven, hilly terrain in terms of total subsistence effort and energy needs has also been emphasized for Lese farmers in Zaire (Jenike et al., 1992).

A third finding is the relative lack of differentiation by wealth and seniority for men in this community. Unexpectedly, ownership of a cattle shelter (an index of land, animal, and labor resources) does not affect men's time allocation or energy expenditure values, although it does for women (while men use shelters extensively, women stay there overnight only when a male relative is present). Household status or age make some impact on time allocation, but not on TEE. An egalitarian and flexible organization of labor is adopted, whereby any one household member can assume multiple demands of work on the mountainside. Inter-individual flexibility is at a premium, precluding a rigid differentiation between men within or between households. This strategy helps to exploit a large area on the mountainside under conditions of chronic and acute shortages of humanpower (Panter-Brick, 1989).

In summary, considerable attention has been devoted to the measurement of physical activity in subsistence populations, especially in energy-limiting or demanding environments (James et al., 1988). Conventionally, PAL have been graded using the FAO/WHO/UNU (1985) values originally proposed to estimate energy requirements for given levels of occupational work. However, the use of sex-discrepant thresholds to grade moderate and heavy physical activity can mask significant sex variation; simple male/female PAL ratios may prove more helpful. Furthermore, detailed data on time use and the energy cost of habitual tasks are needed to reveal the nature of workloads, in order to highlight which time- or power-demanding tasks significantly contribute to observed levels of energy expenditure.

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